Study of $\phi$-N interaction at LEPS2

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\(\phi\)-nucleon interactions

- Contributions from quark exchanges are suppressed.
- Unique place to study multi-gluon exchange processes.
- Not well-studied because of difficulties in making \(\phi\)-meson beam.
Vector Meson Dominance (VMD)

- Photon $J^{PC} = 1-$
- Vector mesons ($\rho,\omega,\phi,J/\psi \ldots$) $J^{PC} = 1-$

\[ \Delta t \approx \frac{2E_\gamma}{m_{VM}^2} \approx 1\text{ fm} / c \]

for $\phi$-meson, $E_\gamma = 3$ GeV
Diffreactive $\phi$ photoproduction on proton

$\gamma \rightarrow \phi$

X=Pomeron...

$\gamma p \rightarrow \phi p$

$E_\gamma$ dependence is not understood by the theory

LEPS/SAPHIR inconsistency
CLAS g10 proton data

\[ \gamma p \rightarrow \phi p \]

**Study of \(\phi\)-N interaction at LEPS2, T. Mibe, 1/9/2007**

*Preliminary*
CLAS g11 proton data
\[\gamma p \rightarrow \phi p\]
Diffreactive $\phi$ photoproduction on proton

\[ \gamma \rightarrow \phi \]

\[ p \rightarrow p \]

New results from two independent data from CLAS.

Good consistency with LEPS data.
At LEPS2

- Improved measurements of dσ/dt at t=−|t|\textsubscript{min} with proton target
  - Wide energy range (E_γ=1.6-6 GeV)
  - Without extrapolation from larger −t
  - Good forward-angle coverage is essential (challenging to current/future facilities at Jlab)

- Coherent production off of deuteron (l=0)
  - Isospin filtering
  - Extension of current efforts by Chang, Horie, Shimizu et al.
VMD and total $\phi$N cross section

- Vector meson dominance
  \[ T_{\gamma N \rightarrow \phi N} = \alpha_{\gamma \phi} T_{\phi N \rightarrow \phi N} \]

- Optical theorem
  \[ \sigma_{\phi N} = 4\pi \text{ Im}(T_{\phi N \rightarrow \phi N}) \]

- Diff. cross section at $t=0$
  \[ \left. \frac{d\sigma_{\gamma N \rightarrow \phi N}}{dt} \right|_{t=0} = \alpha_{\gamma \phi}^2 \frac{p_{\phi}^2}{p_{\gamma}^2} \left(1 - \beta^2\right) \sigma_{\phi N}^2 \]

- VMD estimate, $\sigma_{\phi N} \sim 10$-12 mb
\( \sigma_{\phi N} \) from A dependence

- \( \sigma_{\phi N}^{\text{inel}} \) is measured by a nuclear transmission factor (\( T_A \)) from A-dependence:
  \[
  T_A = \frac{\sigma_{\gamma A \rightarrow \phi X}}{A \sigma_{\gamma N \rightarrow \phi X}}
  \]

- LEPS data (\( E_\gamma = 1.6-2.4 \text{ GeV} \)) on A-dependence:
  \( \sigma_{\phi N}^{\text{inel}} = 35^{+17}_{-11} \text{ mb} \)

- Much larger than VDM estimate
  \( \sigma_{\phi N} = \sigma_{\phi N}^{\text{el}} + \sigma_{\phi N}^{\text{inel}} = 10-12 \text{ mb} \)

Coherent $\phi$-meson photo-production on deuterium

- Single scattering
  \[ \gamma + d \rightarrow \phi + d \]
- Double scattering
  \[ \gamma + d \rightarrow \phi + d \]

Same model successfully describes $\rho$-meson data with known $\sigma_{\rho N}$

Model: T. Rogers, M. Sargsian, M. Strikman
Coherent $\phi$-meson photo-production on deuterium

- Vector Meson Dominance
- $T_{\gamma N \rightarrow \phi N} = \alpha_{\gamma \phi} T_{\phi N \rightarrow \phi N}$

No experimental justification at low energy
Coherent $\phi$-meson photo-production on deuterium

- Non-VDM case
- $T_{\gamma N \to \phi N} \neq \alpha_{\gamma \phi} T_{\phi N \to \phi N}$
- $T_{\phi N \to \phi N} = \sigma_{\phi N} (i+\beta) e^{b/2 t}$

![Graph showing the relationship between $E_{\gamma}$ and $d\sigma/dt$ for different models and experimental data.](image)
**φ-N cross section**

- Tantalizing difference in $\sigma_{\phi N}$ estimated from $\gamma p$ data (10-12mb) and LEPS $\gamma A$ data (~30mb).

- **New CLAS deuteron data**
  - Data is consistent with 10mb in the framework of VMD. Inconsistency with $\gamma A$ data remains.
  - Larger $\sigma_{\phi N}$ from $\gamma A$ data can be understood if the t-slope for the reaction $\phi N \rightarrow \phi N$ is larger than the reaction $\gamma p \rightarrow \phi p$.

- **Larger t-slope → Larger interaction radius** (cross section)
  - Are we really measuring $\sigma_{\phi N}$ ?
  - If so, what makes $\phi$-meson fat ?

- Apparently, there is something beyond the VMD picture.
At LEPS2

- Photon energy dependence of $\phi$ meson absorption in nucleus
  - Extension to previous $\gamma A$ measurement (by Ishikawa et al., $E_{\gamma}<2.4$ GeV)
  - VMD should work better at higher photon energy.

\[
\Delta t \approx \frac{2E_{\gamma}}{m_{VM}^2}
\]

If multi-step process like $\gamma N \rightarrow \omega N, \omega N \rightarrow \phi N$ were important, data would never reach the VMD value.
Summary

- Two mysteries as of 2004
  - $E_\gamma$ dependence of $\gamma p \rightarrow \phi p$ cross section in LEPS $\gamma p$ data
  - Larger $\sigma_{\phi N}$ in LEPS $\gamma A$ data

- CLAS is in the game now. New results from CLAS make things clearer. But not yet fully understood.

- LEPS2 could make major contribution to the issues of $\phi$-N interaction.
Lead investigators

- H. Gao (Duke), K. Hicks (Ohio), K. Kramer (Duke), T. Mibe (Ohio), S. Stepanyan (Jlab), D. Tedeschi (USC).
- and the CLAS collaboration

- Theoretical supports from
  - T. Rogers, M. Strikman (PSU), M. Sargsian (FSU)
  - A. Titov (RIKEN, JINR)
  - J-M. Laget (CEA Saclay)